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Design of a Coliseum

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DESIGN OF A COLISEUM

BY

EDWARD ROMAIN TARNOSKI

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED JUNE, 1907

COLLEGE OF ENGINEERING

May 25, 1907.

This is to certify that the following thesis prepared under the immediate direction of Mr. C. W. Malcolm, Associate in Structural Engineering, by

EDWARD ROMAINE TARNOSKI

entitled DESIGN OF A COLISEUM BUILDING

is accepted by me as fulfilling this part of the requirements for the Degree of Bachelor of Science in Civil Engineering.

Ira O. Baker

Head of Department of Civil Engineering

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DESIGN OF A COLISEUM BUILDING.

INTRODUCTION.

The writer has undertaken this thesis with the hope of learning the essential points concerning the practical design of a coliseum building. It can therefore be seen that this work has been taken up more from a standpoint of learning than of establishing mere facts.

Not being thoroughly acquainted with the general construction of coliseum buildings, the few available designs of such structures have been carefully studied, and the facts gained from these designs have been used. In beginning this design, the writer was undecided as to which he should use, a two-hinged or a three-hinged arch; but after carefully comparing both it was found that the latter could be constructed more economically, and the stresses computed by a shorter and more efficient method.

The general dimensions of the building are as follows: Floor space 200 feet by 296 feet, height 90 feet. The coliseum is to contain nine trusses, these trusses being spaced 37 feet apart, the details of which are shown in Plate 2. The roof covering is composed of corrugated iron and three layers of asphalt paint.

The building was designed so as to conform to the specifications given in Ketchum's "Steel Mill Buildings."

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LOADS.

The following loads were used:

Dead load, 20 lbs. per sq. ft. hor. projection.
Min. Snow load, 10 " " " " " "
Max. " " 20 " " " " " "
Wind pressure, 30 " " " " on a vertical surface.

As the pitch of the arch changes at each panel point, it was necessary to compute each angle that the exposed roof makes with the horizontal. The angle for each panel is shown in the table below:-

Member	Angle in Degrees with Horizontal.
2 - x	90
4 - x	90
6 - x	90
8 - x	59.5
10 - x	38.2
12 - x	23.25
14 - x	18.3
16 - x	14.0
18 - x	7.8
20 - x	1.02

The normal wind load was computed from Duchemin's formula,

$$P_n = P \frac{2 \sin A}{1 + \sin^2 A} ,$$

where,

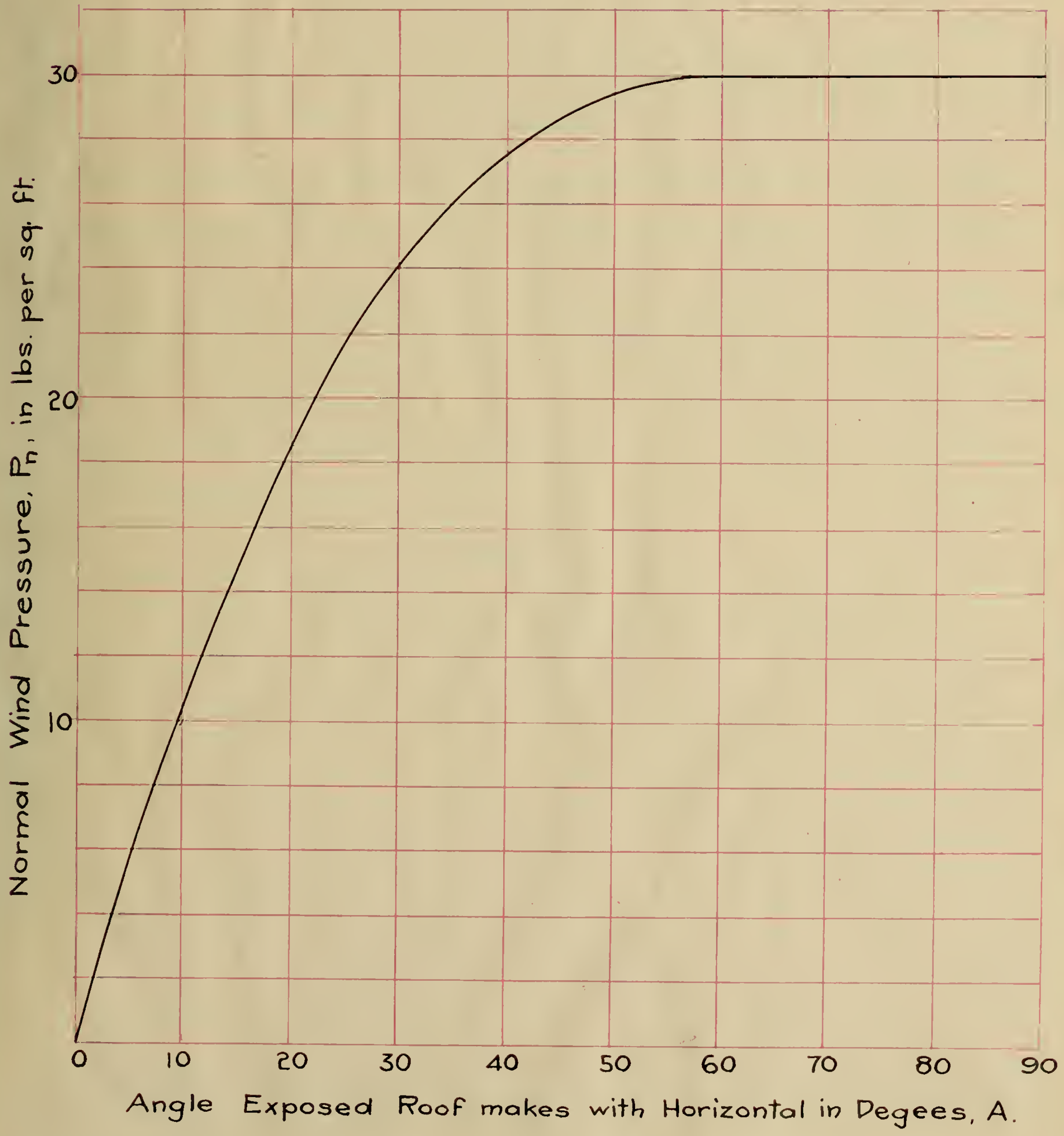
P_n is the normal component of the wind pressure,

P is the pressure per square foot on a vertical surface,

A is the angle of inclination of the roof with the horizontal.

The above equation was solved and the results plotted, as shown on page 4, for a pressure, P, of 30 lbs.

DIAGRAM SHOWING WIND PRESSURES ON INCLINED SURFACES.



In this thesis, tension is denoted by a positive (+) sign, and compression by a negative (-) sign. The nomenclature used to designate the members of the arch is shown in Plate 1.

The stresses in the different members of the arch are figured by graphic resolution. The algebriac mode of solution would involve many difficulties, on account of the constant change in angle that the members make with each other.

Three stress diagrams were constructed, namely; one for the leeward, another for the windward side of the arch, and one for dead load. The diagrams are shown in Plate 1, Fig. 1, Fig. 2, and Fig. 3. The arch is shown in the lower right hand corner, and a table showing stresses, combination of stresses, and maximum stresses is shown in the upper right hand corner of Plate 1. The stresses are given in kips or 1000 pounds.

PERMISSIBLE STRESSES.

From Ketchum's Specifications, the allowable unit tensile stresses in pounds per square inch are as follows:

Shapes, main members, net section	16,000 lbs. per sq. in.
Bars	16,000 " " " "

The allowable Unit Compressive stress was obtained from the formula,

$$S = 16000 - 70 \frac{l}{r},$$

where ,

S = allowable unit stress in pounds per square inch;

l = length of member in inches, center to center of end connections;

r = least radius of gyration of the member in inches.

DESIGN OF MEMBERS.

Only one or two examples showing the method of the design of members will be shown here, since the others were figured in a manner somewhat similar.

Member = Y - 5. Stress = -386.9 kips.

Length of member = 180 inches.

From Ketchum's Specifications, "No compression member shall have a length exceeding 125 times its least radius of gyration for main members, nor 150 times its least radius of gyration for laterals and submembers."

The member will be made up of two 10 inch channels, and if necessary flats and side plates will be used.

Try 2 channels 10" x 25#.

From Carnegie, page 101, the least radius of gyration, r, is 3.52.

Least r = 3.52

Allowable unit stress

= 16000 - 70 l/r

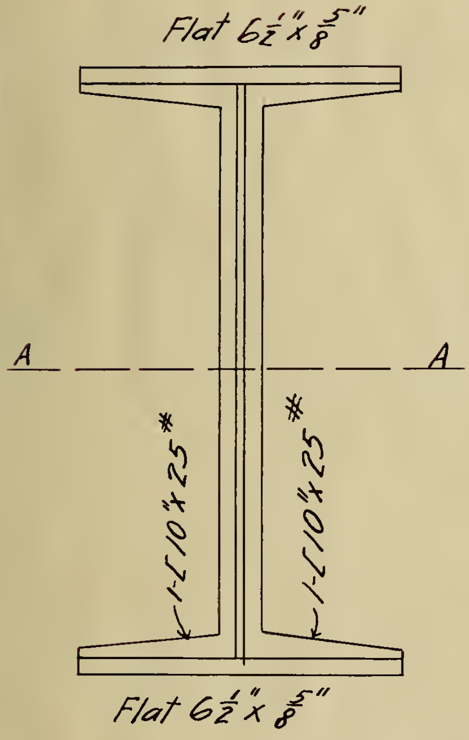
= 16000 - 3580

= 12,420.

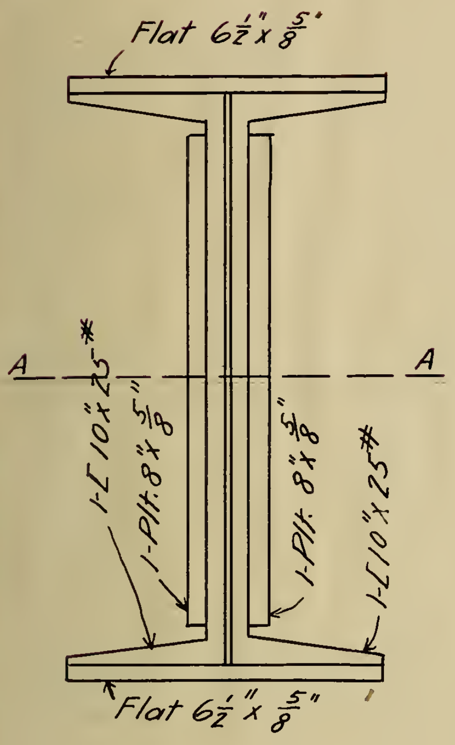
Area required = 386900/12,420
= 31.2 sq. in.

The area of two channels is 14.7 sq. in., which is too small.

Try 2 channels 10" x 25 # ,
and 2 flats 6-1/2" x 5/8".
Area of channels = 14.7 sq. in.
" " flats = 8.12 sq. in.
Total = 22.82 sq. in.
I of flats = $1/12 \times 6.5 \times 0.625^3$
= 0.133
$I_{AA} = 2 \times 0.133 + 2 \times 4.06 \times 5.312^2.$
= 230.3
I of channels = 2 x 91 = 182.
Total I = 230.3 + 182.0 = 412.3.
$r = \sqrt{412.3/22.82}$
= 4.31
1/r = 180/4.31 = 41.5
Allowable unit stress = $16000-70\frac{1}{r}$
= 16000-2902
= 13,098.
Required area = 386900/13098
= 29.6 sq. in.



The area of two channels and flats = 18.76 sq. in., which is still too small.



Try 2 channels 10" x 25#

2 flats 6-1/2 x 5/8"

2 side plates 8" x 5/8"

I_{AA} of flats as before = 230.3

I_{AA} of channels = 182.0

I_{AA} of side plates = 1/12 x 0.625 x 8^3

= 53.26.

Total I_{AA} = 465.56.

Area of 2 channels = 14.7

" " 2 flats = 8.12

" " 2 plates = 10.0

Total area = 32.82 sq. in.

$$\text{Least } r = \sqrt{\frac{456.56}{32.82}}$$

= 3.78

1/r = 180/3.78 = 47.7

Allowable unit stress = 16000 - 70 1/r

= 16000 - 3335

= 12,665

Required area = 386900/12,665

= 30.7 sq. in.

The area of two channels, two flats and two side plates is 32.72 sq. in., which can be used.

The tension members were designed in somewhat the same manner. Allowance was made for net and gross area, throughout the design of tension members.

A table showing the composition of the different members of the arch is given on pages 9 and 10.

Member	Composition.
x - 1	2 channels 10" x 15#
1 - 2	2 angles 3-1/2" x 3" x 5/10"
y - 1	2 channels 10" x 25#
x - 2	2 " 10" x 15#
2 - 3	2 angles 3-1/2" x 3-1/2" x 11/16"
y - 3	2 channels 10" x 25#, 2 plates 6-1/4" x 5/8"
3 - 4	2 angles 4" x 4" x 3/4"
x - 4	2 channels 10" x 25#
4 - 5	2 angles 3-1/2" x 3-1/2"x 11/16"
y - 5	2 channels 10" x 25#, 2 plates 8" x 5/8", and 2 plates 6-1/2" x 5/8"
5 - 6	2 angles 6" x 6" x 3/8"
x - 6	2 channels 10" x 25#
6 - 7	2 angles 6" x 6" x 7/16"
y - 7	2 channels 10" x 25#, 2 plates 8" x 1/2", and 2 plates 6-1/2" x 5/8"
7 - 8	2 angles 5" x 5" x 1/2"
x - 8	2 channels 10" x 25#, 2 plates 6" x 3/8"
8 - 9	2 angles 6" x 6" x 5/8"
y - 9	2 channels 10" x 25#, 2 plates 8" x 3/8", and 2 plates 6-1/4" x 5/8"
9 - 10	2 angles 3" x 3" x 1/4"
x - 10	2 channels 10" x 20#
10 - 11	2 angles 6" x 6" x 7/16"
y - 11	2 channels 10" x 25#, 2 plates 8" x 1/4", and 2 plates 6-1/4" x 5/8"

Member	Composition.
11 - 12	2 angles 3" x 3" x 3/8"
x - 12	2 channels 10" x 20#
12 - 13	2 angles 6" x 6" x 3/8"
y - 13	2 channels 10" x 25#, 2 plates 6-1/4" x 5/8"
13 - 14	2 angles 3" x 3" x 3/8"
x - 14	2 channels 10" x 20#
14 - 15	2 angles 6" x 6" x 7/16"
y - 15	2 channels 10" x 25#, 2 plts. 6-1/4" x 3/8"
15 - 16	2 angles 3" x 3" x 3/8"
x - 16	2 channels 10" x 15#
16 - 17	2 angles 4" x 4" x 1/2"
y - 17	2 channels 10" x 25#
17 - 18	2 angles 3" x 3" x 3/8"
x - 18	2 channels 10" x 15#
18 - 19	2 angles 4" x 4" x 7/16"
y - 19	2 channels 10" x 25#, 2 plts. 6-1/4" x 3/8"
19 - 20	2 angles 3" x 3" x 7/16"
x - 20	2 channels 10" x 15#
20 - 21	2 angles 3" x 3" x 1/4"
y - 20	2 channels 10" x 15#
x - 20	2 channels 10" x 15#

The required number of rivets was figured for shear and bearing, and the one giving the most rivets was used. The number of rivets in each joint, as well as the spacing, can be seen by referring to Plate 2.

ROOF COVERING.

The roofing is to be composed of corrugated steel laid on plank sheathing, which is supported directly upon the purlins. The roofing is to be painted with three coats of asphalt paint, so as to protect it from corrosion. Barbed roofing nails, two inches in length will be used in fastening the corrugated steel to the sheathing. The nails are to be spaced eight inches apart.

PURLINS.

The arches are spaced 37 feet center to center, and are braced by means of purlins and laterals. Simple trussed purlins are placed at 18 - 19, 14 - 15, 10 - 11 and 7 - 8. The spaces left between are braced with 3-1/2 x 3 x 1/4 inch angles. The details of these can be seen in Plate 2.

The trussed purlins are composed of four angles 4" x 4" x 1/2", and are laced with 3"x3"x1/4" angles, the depth of each depending upon its position.

MINOR DETAILS.

Details of pins, pin connections, cover plates, splice plates, etc., will not be explained in full, since a better idea of these can be obtained by referring to Plate 2.

PLATE I

STRAIN SHEET

MEMBERS	DEAD LOAD	MIN SNOW LOAD	MAX SNOW LOAD	WIND LOAD + DEAD LOAD		WIND + MIN SNOW + DEAD LOAD		MAX SNOW + DEAD LOAD	MAX STRESS
Y-1	-126.8	-41.2	-82.4	-118.1	-165.3	-159.3	-206.5	-208.0	-208.0
X-1	-7.8	-2.6	-5.2	-6.9	+4.2	-16.6	+1.6	[illegible]	[illegible]
1-2	+6.0	+2.0	+4.0	+51.4	-3.6	+54.4	-1.6	+10.0	+54.4
X-2	-4.9	-1.6	-3.2	-4.5	+2.6	[illegible]	+0.9	[illegible]	[illegible]
2-3	+72.5	-24.2	+48.4	+10	+110.5	[illegible]	+134.7	+120.9	+134.7
Y-3	-164.0	-54.7	-108.4	[illegible]	-226.2	-157.6	-280.9	-272.4	-280.9
3-4	-47.6	-15.7	-31.4	[illegible]	-73.0	-31.3	-88.7	-79.2	-88.7
X-4	[illegible]	+16.6	[illegible]	+45.4	[illegible]	+39.6	+100.6	+80.9	+100.6
4-5	+72.2	+24.1	+48.2	[illegible]	+110.7	+87.4	+134.6	+120.4	+134.6
Y-5	[illegible]	[illegible]	-141.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5-6	-44.2	-14.7	-29.4	-32.1	-67.6	-46.8	-92.3	-73.6	-92.3
X-6	+105.2	+35.1	+70.2	-6.2	+171.2	[illegible]	+206.3	+175.4	+206.3
6-7	-43.1	-14.4	-28.8	-15.1	-56.5	-29.5	-70.9	-71.9	-71.9
Y-7	-203.4	-67.1	-135.4	-119.2	-292.8	-186.9	-360.5	-338.8	-360.5
7-8	-18.5	-6.2	-12.3	+7.8	-42.8	+1.6	-49.0	-30.8	-49.0
X-8	+85.0	[illegible]	+56.6	-31.4	+146.1	[illegible]	+174.4	+141.6	+174.4
8-9	[illegible]	-17.4	-34.8	[illegible]	-61.7	-63.7	-79.1	-84.1	-84.1
Y-9	-188.6	[illegible]	-125.6	-95.6	-284.5	-158.4	[illegible]	-314.2	[illegible]
9-10	+16.7	[illegible]	+11.2	[illegible]	[illegible]	+42.8	[illegible]	+27.8	[illegible]
X-10	+70.7	[illegible]	+46.8	[illegible]	+135.7	-19.7	+159.1	+117.4	+159.1
10-11	-55.8	-17.8	-35.8	[illegible]	[illegible]	-67.1	-80.9	-86.2	[illegible]
Y-11	-165.8	[illegible]	-110.6	-62.1	-267.8	-117.4	-323.1	-276.4	-323.1
11-12	+32.6	+10.9	+21.7	+50.4	+21.7	+61.3	+32.6	+54.3	+61.3
X-12	+53.1	+17.7	+35.4	-81.9	+134.1	-64.2	+151.8	+88.5	+151.8
12-13	-43.1	-14.4	-28.8	-45.0	-47.6	-59.4	-62.0	-71.9	-71.9
Y-13	-137.1	-45.7	-91.4	[illegible]	-244.6	-69.0	-290.3	-228.5	-290.3
13-14	+37.6	+12.5	+25.0	+37.1	+36.6	+49.6	+49.1	+62.6	+62.6
X-14	+30.5	+10.2	+20.4	+164.1	+101.7	+174.3	+11.9	+50.8	+174.3
14-15	-41.0	-13.7	-27.4	-26.0	-53.0	-39.7	-66.7	-68.4	-68.4
Y-15	-106.2	-35.4	-70.8	+5.5	-212.4	-28.9	-247.8	-177.0	-247.8
15-16	+37.1	+12.4	+24.8	+16.3	+45.9	+28.7	+58.3	+61.9	+61.9
X-16	+5.0	+16.7	+23.4	-111.8	+68.2	-95.1	+84.9	+28.4	-111.8
16-17	-33.8	-11.3	-22.6	-7.6	-53.0	-18.9	-64.3	-56.4	-64.3
Y-17	-68.7	[illegible]	-46.4	+22.2	-165.9	+1.0	-189.1	-116.1	-189.1
17-18	+30.2	+10.1	+20.2	-12.3	+56.2	-2.2	+66.3	+50.4	+66.3
X-18	-17.3	-5.7	-11.5	[illegible]	+24.0	-104.1	+18.2	-28.8	-104.1
18-19	-24.3	-8.1	-16.2	+8.7	-51.1	+0.6	-59.2	-40.5	-59.2
Y-19	-41.8	-13.9	-27.6	+11.6	-112.7	-2.3	-126.6	-69.6	[illegible]
19-20	+18.8	+6.3	+12.5	-32.0	+62.4	-25.7	+68.7	[illegible]	[illegible]
X-20	-31.7	-10.6	-21.2	[illegible]	-27.7	-70.4	-38.3	[illegible]	[illegible]
20-21	+7.8	+2.6	+5.2	[illegible]	[illegible]	+32.2	[illegible]	[illegible]	[illegible]
X-21	-36.3	-12.1	-24.2	-80.1	-31.6	-92.2	-43.7	[illegible]	[illegible]
Y-21	-30.7	-10.3	-20.5	[illegible]	-71.0	-30.9	-81.3	[illegible]	-81.3

WIND LOAD
STRESS DIAGRAM
FOR
WINDWARD SIDE

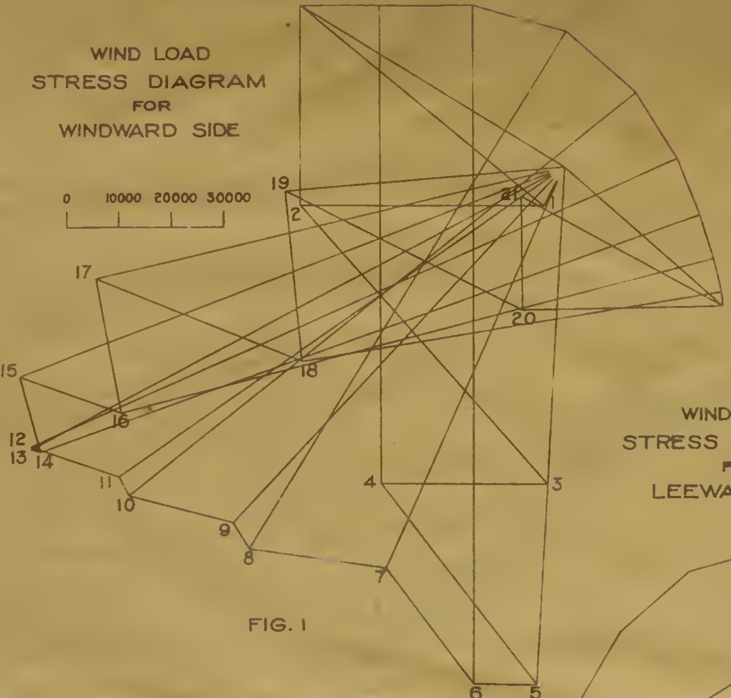


FIG. 1

WIND LOAD
STRESS DIAGRAM
FOR
LEEWARD SIDE

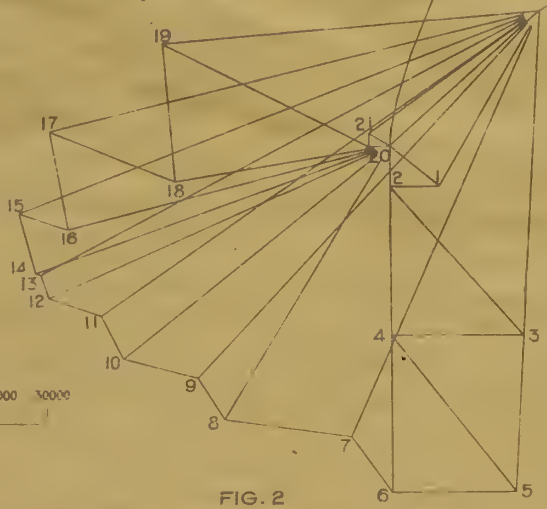


FIG. 2

DEAD LOAD
STRESS DIAGRAM

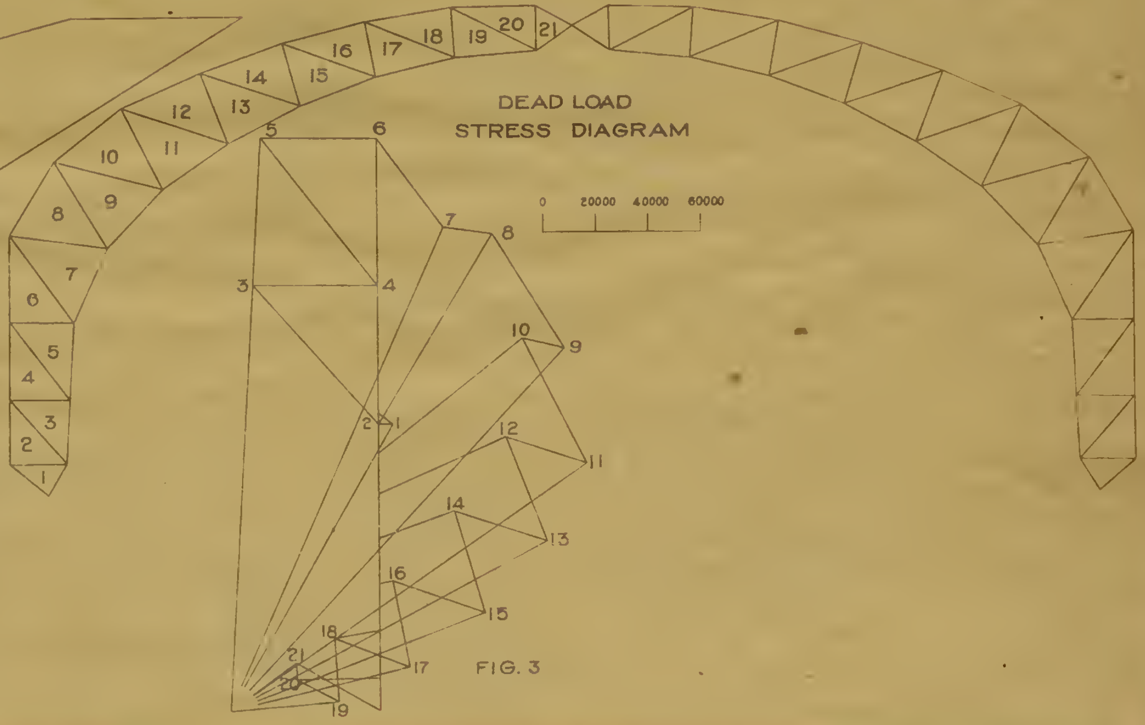
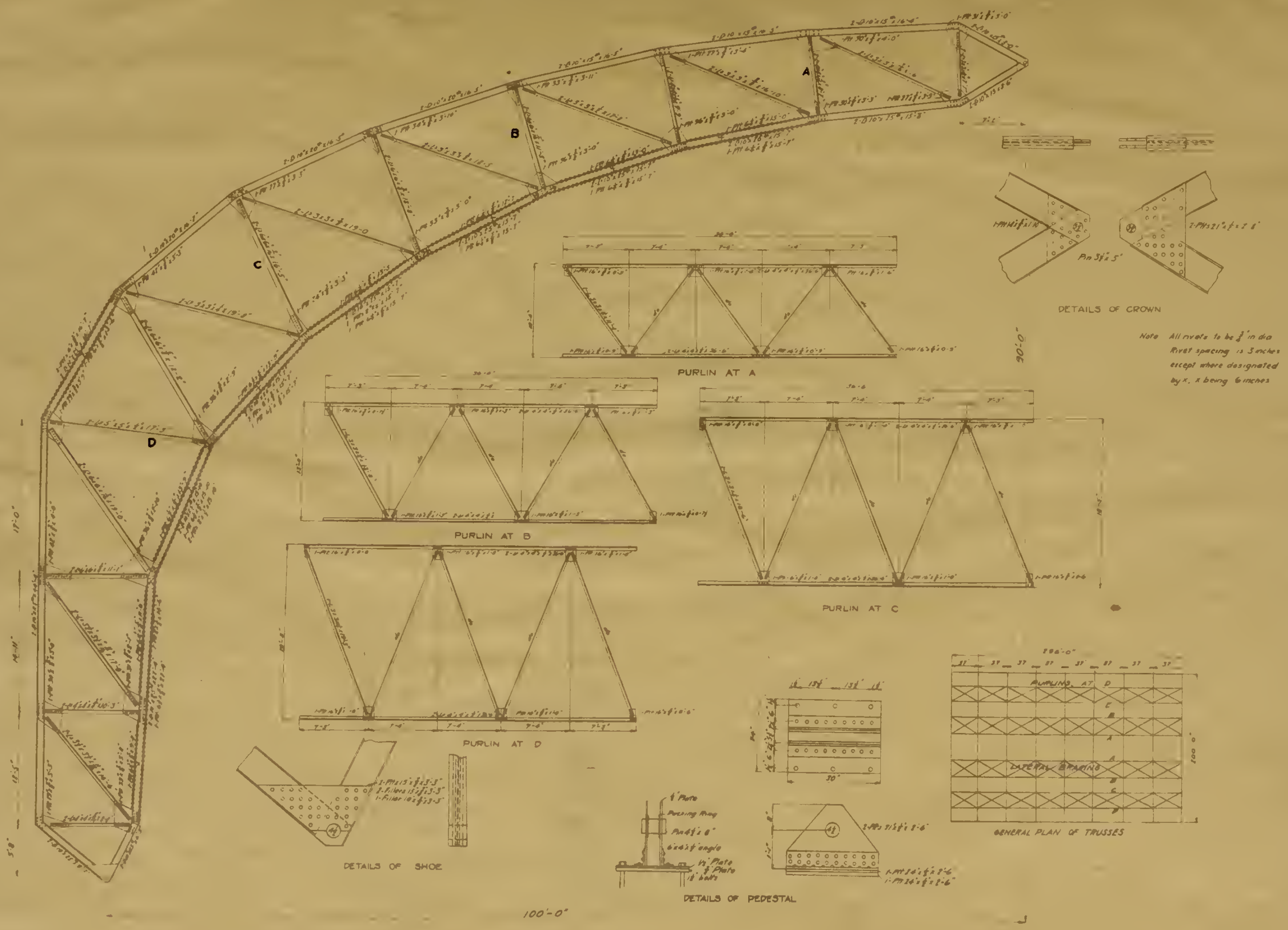


FIG. 3

PLATE 2
DETAILS



Note All rivets to be ¾" in dia
Rivet spacing is 3 inches
except where designated
by x, x being 6 inches

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